Army Research Laboratory

Army Illumination Model v2
User's Manual

by Richard C. Shirkey

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14. ABSTRACT

The Army increasingly relies on night operations to accomplish its objectives. These night operations frequently require using Night Vision Goggles and other light-sensitive devices which are strongly affected by ambient lighting, a large component of which is urban. Presented herein is a user’s manual for the Army Illumination Model v2 (AIM v2). AIM v2 calculates the brightness, either broadband or spectral, at wavelengths from 0.35 to ~1.1μm from urban sources. AIM v2 determines this brightness for either a point or extended source under a fairly clear atmosphere; transmission through and reflection by nine cloud types are available as is Lunar illumination as a function of time-of-day and location. For areas devoid of electrical power, AIM can calculate brightness levels from lanterns using either liquid or pressurized fuels.

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1. Introduction

The Army Illumination Model version 2 (AIM v2), calculates the brightness from either a point source or an extended source dependent upon observer distance from the source (city). AIM runs in batch mode must be compiled with a FORTRAN 95 compiler that has an available double precision switch that effectively changes all internal code variables, which are written in real(4), to real(8). For extended sources AIM performs its calculations over a rectangular grid in Cartesian coordinates using the extended trapezoidal rule; for point sources, the grid is not required or calculated. The program has been structured to take advantage of geometrical symmetry where the city is considered circular. All X-axis values, but only positive Y-axis values are calculated with the final output being doubled where appropriate. The methodology for calculation of the broadband and spectral brightness may be found in Shirkey (*1*). Brightness levels, a function of city population and light types, atmospheric molecular and aerosol content, may be calculated at any distance from the city, including internal to the city, and are calculated under realistic atmospheric conditions that includes clear skies, partly cloudy and overcast conditions, and fog. The calculation of transmission of lunar light through the clouds is based upon a three-layer radiative transfer model developed by Shapiro (*2*). Background airglow is included (*3*) as is lunar illumination as a function of time and location (*4*). Using the spectra of the city light types from 0.35 to 0.90 μm, the calculated broadband brightness is broken down into spectral radiances. Light spectra are available out to 2.5 μm for use with near- or far-IR sensors.

The basic scenario for city brightness determination is shown in figure 1in a Cartesian coordinate system with horizontal axis X,Y. In general, light from an elemental area (a) of the city (C) is propagated along the light "beam" for a distance S where it is subsequently scattered into the observer's line-of-sight (LOS) U. The city, of radius R, is at a horizontal distance D from the observer, O, who, in turn, can be at an altitude A above the city looking at zenith angle Z_o and azimuth angle β along the LOS; B is the city-level projection of O. In essence, the brightness along the LOS is found by integrating from the observer to a maximum LOS distance where S varies due to the numerical integration steps along the LOS. The maximum distance along the LOS is set to 40 km when clouds are not present and is limited to a slant distance determined by the cloud base height (h_c) when clouds are present. An approximate method, first developed by Treanor (*5*) and modified by Garstang (*6*), includes the direct beam and light scattered along path S with subsequent single scattering into the LOS. Since extended source calculations are performed over a pseudo 3-dimensional rectangular grid, brightness effects and associated parameters can be examined using optional file output.

The program includes data files for the city population (city_info.dat) and light spectra (light_spectra.dat). The available city populations, including latitude and longitude (decimal degrees), may be found in appendix A. The program default values are clear atmosphere, no

clouds, and light types of clear mercury, high pressure sodium and metal halide with percentages as found in table 3. Optional diagnostic and plotting files are available for detailed examination of various intermediate parameters if so desired.

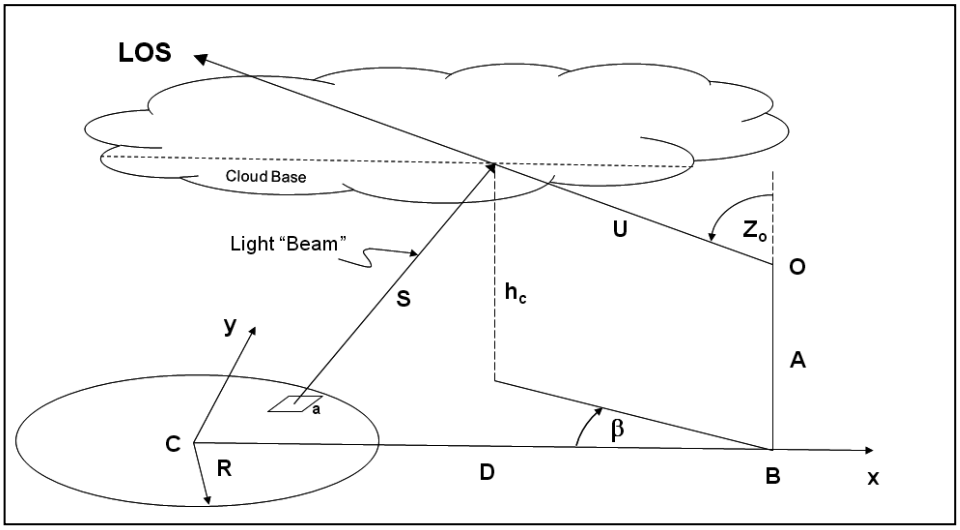

Figure 1. Geometry for input.

2. Program City Bright

City_bright controls the flow of execution with "clear" air calculations (i.e., only molecules and aerosols) being performed first and cloud calculations being performed after.

Dependent upon the observer's distance from the city, one of two calculations will be selected automatically by the program. If the observer to city-center distance is greater than ~2.25 times the city radius, the source is considered to be a point, otherwise it is considered as an extended source.

2.1 Input Variables and Their Usage

The seven required and one optional input record and their parameter meanings are described in table 1 and detailed in the paragraphs below where the parameter name is in *italics*. All inputs are free format with a space between parameters. Minor error checking is done.

Table 1. AIM input values, their type designation, meaning, units and additional information.

Input Parameter Name*	Type	Meaning	Units	Notes
city_name[1]	character	Name of city		30 characters maximum
city_radius[1]	real	Radius of city	km	
city_ht[1]	real	Altitude of city above sea level	km	Minimal effect on brightness
city_L[1]	real	City luminosity per capita	lumens per head of population	1000 lm/head is suggested
D[2]	real	Horizontal distance from observer to city center or point source	km	
obs_Alt[2]	real	Observer height above city	km	
Zenith[2]	real	Angle between observer's zenith and observer's LOS	degrees	straight up = 0°; nadir = 90°
beta[2]	real	Azimuth angle	degrees	Measured from the city center-observer axis: 0° is “in front” of the observer and 180° is “behind” the observer
K[3]	real	Garstang’s clarity factor *K* which measures the ratio of aerosols to molecules at ground level		*K* Visibility(km) 0.5 48 2.0 14 3.0 9.2
s_albedo[3]	real	Surface albedo		Representative values range from 0.15 (asphalt, dirty concrete) to 0.45 (old snow) to 0.85 (freshly fallen snow)
Fract[3]	real	Fraction of city luminosity escaping above the horizontal from lamp fixtures		10–15% suggested
month[4]	integer	Month of year		2 digits
day[4]	integer	Day of month		2 digits
yr[4]	integer	Year		4 digits
utc[4]	real	UTC time of observer		Equivalent to Zulu or GMT

Table 1. AIM input values, their type designation, meaning, units and additional information (continued).

Input Parameter Name*	Type	Meaning	Units	Notes
w_start[5]	real	Beginning wavelength of interval under consideration	µm	Start point must coincide with a resolution wavelength. Range is 0.35 to 2.5 µm at a resolution of 0.001 µm.
w_end[5]	real	Ending wavelength of interval under consideration	µm	SAB, but end point
percnt(i)[6]	real array	Percents of light type$_{i=1, 9}$ within city		Nine values required - a light type with a 0% is allowed but is not considered in the calculations
cloud[7]	logical	Switch indicating clouds are present		
iprint[7]	logical	Invoke diagnostics		May require an additional record. See appendix A
cld_typ(i)[8†]	integer array	Cloud type for layer i where i = 1 to 3		Layer 1 is highest. required if cloud=.T.
cld_fract(i)[8†]	real array	Cloud fraction for layer i where i = 1 to 3		>0.9 is considered overcast. required if cloud=.T.

* superscripts in the Input Parameter Name column indicate the record number.
† the values for cloud type and cloud amount/fraction are interleaved.

2.1.1 Record 1

2.1.1.1 City Name

The name of the city that is being considered (*city_name*), which may be in upper or lower case or any combination thereof. If the requested city is not in the supplied data base (city_info.dat), the user is asked to supply the needed information—latitude and longitude (east is positive, west is negative) in decimal degrees, population, and country that can optionally be added to the data base.

2.1.1.2 City Radius

The radius, in km, of the city under consideration (*city_radius*).

2.1.1.3 City Height

The height, in km, of the city above sea level (*city_ht*). This information can usually be obtained through Wikipedia. It only affects the Rayleigh scattering and does not influence the observed brightness strongly.

2.1.1.4 City Luminosity

The city luminosity in lumens per head of population (*city_L*). This is simply the total city light output divided by the total city population. While a simple quantity, the easiest way to determine this quantity is to ask the local electric company for types and numbers of the city lights. City populations can be obtained from census figures; however, the population for the selected city may be determined through the associated city data base (assuming the city is in the data base). At typical figure would be 1000 lumens/head of population.

2.1.2 Record 2

2.1.2.1 Distance From Observer to City Center

D is the horizontal distance, in km, from the observer to city center or to a point source if the distance is greater than ~2.25 times the city radius.

2.1.2.2 Observer Altitude

The altitude of the observer, in km, above the city (*obs_Alt*).

2.1.2.3 Zenith Angle

The zenith angle (*zenith*) measured in degrees is the angular amount that the observer is looking relative to the zenith (in astronomical terminology this is known as the zenith distance). In other words, when the observer is looking straight up, the zenith angle is zero degrees, when looking straight down (the nadir) the zenith angle is one hundred and eighty degrees. Alternately, the zenith angle can be thought of as 90° elevation angle, so if one is looking upward at a 10° angle to the surface, the zenith angle would be 80°. Zenith angles can never be negative.

2.1.2.4 Azimuth

Beta is the azimuth angle, in degrees, with respect to the observer's location and the city center (i.e., the observations are "behind" the observer when the azimuth angle is 180° and 0° when the observer is looking toward the city.) Figure 2 (*6*) is an example of the zenith angle used in conjunction with the azimuth angle for the city of Denver. It shows the observed light from Denver at a distance of 40 km at varying zenith angles; the abscissa has been formatted for ease of reading in-so-far as it depicts the zenith angle going from –60° to +60°. However, input of negative zenith angles will generate incorrect results. To generate these results for pseudo negative zenith angles, the azimuth angle was set to 180°.

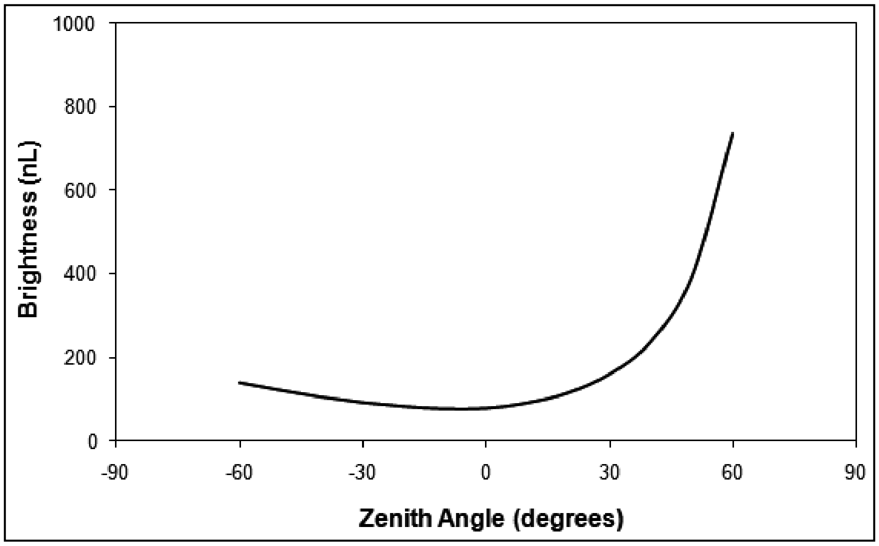

Figure 2. Sky brightness due to Denver as a function of zenith angle at a distance of 40 km from the city.

2.1.3 Record 3

2.1.3.1 Clarity Factor

K is Garstang's (*6*) clarity factor, an indicator of visibility that relates the amount of aerosol particles to that of Rayleigh molecules at ground level. It may also be thought of as an indicator of atmospheric clarity: $K = 0.5$ is a very clear atmosphere corresponding to a visibility of 48 km and $K = 3.0$ is considerably hazier corresponding to a visibility of 9 km.

2.1.3.2 Surface Albedo

s_albedo is the surface albedo (or reflectance) representative of the city. Generally most city light is reflected from streets and parking lots. Representative values range from 0.15 (asphalt, dirty concrete) to 0.45 (old snow) to 0.85 (freshly fallen snow).

2.1.3.3 Fractional Amount of Light in the Upward Direction

Fract is the fraction of light escaping from city lamps above the horizontal and radiated directly into the sky. Do not confuse this parameter with reflected light from surfaces, which is handled by the surface albedo parameter *s_albedo*. This may also be thought of as the fraction of light that escapes from the light fixture in an upward direction. Reasonable values range from 0.10 to 0.15.

2.1.4 Record 4

2.1.4.1 Date and Time

The *month* (1–12), *day* (1–31), 4-digit *year* and coordinated universal time (*UTC*) for the desired location.

2.1.5 Record 5

2.1.5.1 Beginning/Ending Wavelength Interval

These are the beginning and ending (*w_start*, *w_end*) wavelengths, in μm, for the interval under consideration. While the spectral light data base limits are 0.35 to 2.5 μm, the region of validity is for wavelengths from 0.4 and ~1.1 μm.

2.1.6 Record 6

2.1.6.1 Light Type Percents

percnt is an array of the percentage of the nine different light types that may exist in a given city and controls the type of light(s) selected. There are nine light type spectral curves available, however only three have default percents within the program. These percentages dictate what light types/curves will be used to determine the spectral radiances. The author found that local electrical companies are very helpful in obtaining these percentages. The indices of the light types and their corresponding percentages are presented in table 2. Light types that are not considered (i.e., not used in a given city) should have 0 entered as their percent and the total for all light types selected should be 100%. Liquid kerosene and pressurized propane lanterns are supplied for areas devoid of electrical power.

Table 2. Light types available in AIM, their corresponding index and default value.

Light Type	Index	Default Value (%)
Clear Mercury	1	20.2
Low Pressure Sodium	2	0
High Pressure Sodium	3	77.9
Metal Halide	4	1.9
white LED	5	0
Standard Fluorescent	6	0
Incandescent	7	0
Liquid Kerosene	8	0
Pressurized Propane	9	0

2.1.7 Record 7

2.1.7.1 Cloud Control Switch

cloud is a logical variable that controls whether or not clouds are selected.

2.1.7.2 Diagnostic and Plotting Control Switches

The logical variable *iprint* controls whether or not diagnostic and plotting files are created and, in the case of an extended source, how much information is written to file. Appendix B provides additional information.

2.1.8 Record 8

2.1.8.1 Cloud Type

If *cloud* was set to .true, then the cloud type(s) ($cld\_typ_{i=1,\,3}$) are required. There are three cloud layers available, with layer 1 being the upper or highest level, layer 2 being the middle layer and layer 3 being the lowest or bottom layer. The cloud types available along with their base heights in either mean sea level (MSL) or above ground level (AGL), are listed in table 3. The cloud base heights are automatically selected dependent upon the cloud type chosen. The cloud type, interleaved with cloud amount, control how much lunar illumination is attenuated and also how much city light is reflected from the bottommost layer. Cloud reflection is only considered from the lowermost layer.

Table 3. Cloud types available for high, middle, and low layers and their respective cloud base heights.

Layer	Cloud Type	Cloud Selector #	Cloud Base Height (km)
High	Clear	1	40.0
	Thin Ci/Cs	2	9.3 MSL
	Thick Ci/Cs	3	9.3 MSL
Middle	Clear	4	40.0
	As/Ac	5	4.0 MSL
Low	Clear	6	40.0
	Clear w fog/smoke	7	40
	Sc/St	8	1.1 AGL
	Cu/Cb	9	1.2 AGL

2.1.8.2 Cloud Fractional Amount

If *cloud* was set to .true. then the *cld_fract* array, which contains the information about cloud amounts in all three layers, is requested. $cld\_fract_{i=1,\,3}$ corresponds with $cld\_typ_{i=1,\,3}$ where i = 1 is the highest or uppermost layer. This parameter is interleaved with the *cld_type* parameter. Layers with cloud amounts greater than 0.9 are considered overcast.

The program is set up to reflect city radiation from only the bottommost layer, whichever layer (1, 2, or 3) is lowest (if only cirrus was entered, layer 1 would be the only and therefore the lowest layer). When determining reflection from the lowest layer, the program does not currently take into account its fractional amount (the layer is considered overcast for reflection purposes).

2.1.9 Optional Record 9

If *iprint* has been set to .true. and the city is an extended source (D > ~2.25 R), output can be excessive and the user may wish to limit the amount of output written to file. See appendix A, Diagnostic and Plotting Control, for detailed information.

2.2 Sample Input

Below is a sample file (table 4) for determining the scattered light from Denver, which has a radius of 15 km, is at a height of 1.6 km above sea level and has a light output per capita of 1000 lumens (record 1). Record 2 contains the observer information who is 13.6 km from Denver's center is at ground level (altitude of zero km), and is looking straight upward (zenith of zero degrees) towards the city center (azimuth of zero degrees). A fairly clear atmosphere (Garstang clarity factor of 0.5) with a surface albedo of 0.15 and with 15% of the light going directly upward from the fixture is set in record 3. The scenario is for March 2, 2011 at 30 min UTC (record 4) over the wavelength band from 0.4 to 0.7 μm (fifth record). The city light types are comprised of 10% clear mercury, 5% low pressure sodium, 55% high pressure sodium, 20% metal halide and 10% incandescent (sixth record). The scenario includes clouds with detailed diagnostic output requested (record seven); the clouds themselves are comprised of three layers, the high layer containing 10% thin cirrus (Ci)/cirrostratus (Cs), the middle layer containing 10% altocumulus (Ac)/altostratus (As), and the lowest layer comprised of 90% stratocumulus (Sc)/stratus (St) (record 8). Since the source is extended, and write to file has been requested, the optional record 9 requests that no output lines should be skipped but output limits have been placed on the X axis (minimum/maximum X axis values of −2.0 and 2.0 km) and a maximum output limit of 0.1 km on the Y axis.

Table 4. Sample input for AIM.

Input	Parameters	Record #
Denver 15. 1.6 1000.	City name, radius, altitude, lumens/head	1
13.6 0. 0. 0.	Observer's horizontal distance from city center/point source, altitude, zenith and azimuth angles	2
.5 .15 .15	Clarity factor, surface albedo, fraction of light in upward direction	3
3 2 2011 0030.	Month, day, year, UTC	4
.4 .7	Beginning and ending wavelength	5
10. 5. 55. 20. 0. 0. 10. 0. 0.	Light type percents	6
t t	Cloud and diagnostic/plot write switches	7
2 .1 5 .1 8 .9	Cloud type and interleaved cloud amount for cloud layers 1 to 3	8
0 -2. 2. 0.1	Line skip, minimum and maximum X limits, and maximum Y limit, for writing to file	9

2.3 Ancillary Required Files

Additional necessary data in the form of flat American Standard Code for Information Interchange (ASCII) files are provided. These files, their internal connection units, and their content are presented in table 5. There is one output file created, in comma separated value (CSV) format, rad_out.csv. This file holds the output spectral radiance values in nL and $W/m^2/sr/nm$ at 1 nm resolution. All data files are expected to be in directory "data" immediately below the execution directory; output data files are also written to that directory. Input data files have a ".dat" extension; output files are ".csv".

Table 5. Supplied input data files, their name, content, connection unit and brief description.

File Name	Content	Connection Unit	Description
input.dat	User supplied data	20	User supplied information
city_info.dat	City information	cityunit (21)	Supplies city name ,country name, latitude and longitude (decimal degrees), population
light_spectra.dat	Light spectra	lightunit (22)	Spectral curves (0.35–2.5 μm at 1 nm resolution) for the light types in table 2
rad_out.csv	Spectral radiance	radunit (23)	Spectral radiance at 1 nm (0.001 μm) resolution over the selected wavelength interval

3. Output

The output for either clear or cloud runs is quite similar. All initial inputs, and parameters derived from that input, are printed followed by some informative information. For extended sources, the city's broadband brightness for the front and back city halves, the "front" being defined by which half is closer to the observer, are printed. For point sources, front and back nomenclature is irrelevant and the brightness from the back is set equal to –999. At this point in program execution the broadband brightness does not include either lunar or background night-sky values. Information then follows concerning the lunar position and its brightness, followed by the total (= background night-sky + lunar + city) brightness in nanolumens. If any light type(s) have been selected, then the broadband brightness is broken down into spectral intervals of 0.001 μm resolution and every 25th value is printed. The complete spectral radiance is written to file rad_out.csv which will contain the wavelength in nm and the spectral radiances in both nL and $W/m^2/sr/nm$. If clouds have been selected, the previous output is followed by information about the selected clouds. After the cloud information, the output is the same as for the no-cloud case with the exception that the lunar position information is not duplicated and both the broadband brightness and spectral radiances for this scenario include the cloud effects. In essence, there are two separate runs. Appendix B presents the output from the sample input in table 4.

4. References

1. Shirkey, R. C. *Sky Glow from Cities, Atmospheric Illumination Model v2*; ARL-TR-5719; September 2011.

2. Shapiro, R. *Solar Radiation Flux Calculations from Standard Meteorological Observations*; AFGL-TR-82-0039; Air Force Geophysics Laboratory: Hanscom AFB, MA, 1982.

3. Benn, C. R.; Ellison, S. L.; La Palma Night-Sky Brightness, La Palma technical note 115, Roque de los Muchachos Observatory, 2007.

4. Duncan, L. D.; Sauter, D. *Natural Illumination under Realistic weather Conditions: ILUMA, Atmospheric Sciences Laboratory* ; ASL-TR-0221-09; WSMR, NM, 1992.

5. Treanor, P. J. A Simple Propagation Law for Artificial Night-Sky Illumination. *The Observatory* **1973**, *93*, 117–120.

6. Garstang, R. H. Model for Artificial Night-Sky Illumination. *Publication of the Astronomical Society of the Pacific* **1986**, *98*, 364–375.

7. Press, W. H.; Teukolsky, S. A.; Vettering, W. T.; Flannery, B. P. Numerical Recipes in Fortran 77, 2nd edition, v1, Cambridge University Press, 1992.

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Appendix A. Diagnostic and Plotting Control

The program gives the user the option of examining various parameters in detail via either diagnostic or plot output. Write to file of this output is controlled by the variable *iprint*, discussed previously. The diagnostic/plot output requires three additional routines, *diag*, *plot*, and *britesort*; these routines may be removed without affecting the AIM calculations.

A.1 Diagnostic control

If *iprint* has been set to .true. the *diag* routine will output various parameters which are written to a temporary unsorted output diagnostic file, "rawout.txt". The program uses the extended trapezoidal algorithm *trapzd* (*7*) for integration coupled with a degree of accuracy routine *qtrap* (*7*). *trapzd* doubles the number of intervals until the desired degree of accuracy is achieved; however, this technique does not provide sequential values in the LOS distance U since intervals are doubled. Therefore, a subsequent routine, *britesort,* is called that selects and sorts "rawout.txt" over U, resulting in a final output diagnostic file "output.csv". For "output.csv", the "clear" air values are written separated by blank lines at each change in the Y index; if clouds are present the file will also contain values relevant to the cloud calculations. The boundary between these two data types (clear air or clouds) is indicated by a "Clouds follow" flag.

If the source is extended then the routine *plot* writes the X and Y coordinates, their indices, and the brightness for each coordinate to file sb_out.csv. These optional files and their purpose are presented in table A-1.

Table A-1. Optional write data files, their name, content, connection unit and brief description.

File Name	Content	Connection Unit	Description
rawout.txt	Unsorted diagnostic output for extended city or point source	diagunit (25)	Temporary
output.csv	Rawout.txt sorted on LOS distance U	diagunit+1	Optional: contains numerous intermediate values (see table 5)
sb_out.csv	Surface brightness for extended sources only	plotunit (24)	Optional: surface brightness at all grid points

If the diagnostic write routines are invoked *and the source is extended*,the output file output.csv may be extremely large as information is written to file at each XY coordinate point. For this reason there are additional input parameters, presented in table A-2, that control writing to this file. Since point sources do not require a city grid, the output is not excessive and the parameters in table A-2 are not required; if the source is extended and *iprint* = .true., the program will be looking for record 10 (table A-2). User control over the amount of output written is controlled

by either skipping file writes or by constraining the output to specific, user entered X and Y axis limiting values.

Table A-2. Optional diagnostic input parameters and their meaning.

Input Parameter	Type	Meaning
Line_skip[10]	integer	Print every Line_skip (≤ 9) line; avoids excessive diagnostic file size
xmin[10]	real	Limiting X axis factor for diagnostic output
xmax[10]	real	Limiting X axis factor for diagnostic output
ylim[10]	real	Limiting Y axis factor for diagnostic output:

* superscripts in the Input Parameter Name column indicate the record number.

In passing we note that the criterion for determining whether a source is a point or extended depends on the observer distance and city radius; if the distance to the observer is greater than the square root of epsilon (ε) times the city radius, $D \geq R\, \varepsilon^{-\frac{1}{2}}$, the source is considered to be extended. ε may be thought of as the fractional acceptable error. Within the program (module "parameter") $\varepsilon = 0.20$, which translates to the observer's distance from city center or point source being greater than ~ 2.25 times the city radius for the source to be considered as extended.

A-1.1 Number of lines to skip

Line_skip controls how many lines of output are written to file by skipping every *Line_skip* lines.

A-1.2 X-axis limitation

Minimum and maximum X coordinate values (*xmin, xmax*) to not write to file, i.e. if xmin = –7 (negative X axis) then output with X coordinates less than −7 will not be printed. xmax has a similar meaning for the positive X axis.

A-1.3 Y-axis limitation

ylim is analogous to xmin and xmax. Since the city is symmetrical, only brightness for the positive Y axis is calculated. This parameter will stop output for y coordinate values greater than ylim.

A-2 Diagnostic Output Parameters

The output parameters from *diag* and their meaning are presented in table A-3. Note that for a point source, the information in table A-3 is written at each integration step; if the city is extended, the information is again written at each integration step but now for each grid point, leading to possible excessive output as discussed above. Figure A-1 is a graphical representation of certain of these parameters.

Table A-3. Diagnostic output parameters and their meaning.

Parameter Name	Parameter Meaning	Units	Notes
city_ht	City height	km	Has minimal effect on brightness.
city_radius	City radius	km	
obs_Alt	Observer altitude	km	
D	Horizontal distance from observer to city center	km	
delta	Grid spacing	km	city_radius/100
h	Height of scattering point	km	This is the vertical height at the integration point U.
S	Distance from city emission point to scattering point on LOS	km	This is the slant height at the integration point U.
U	LOS distance	km	
L	Slant distance from observer to city emission point	km	
X	X array grid point	km	
Y	Y array grid point	km	
ix	X array grid index	—	
iy	Y array grid index	—	
beta	Azimuth	degrees	
zenith	Zenith	degrees	
theta	Angle between LOS and L	degrees	
phi	Angle between L and s	degrees	
psi	Angle between emission point zenith and s	degrees	
s_ang	Scattering angle	degrees	theta + phi
b	Broadband brightness	nL	
extn_xq	Extinction along upward path	—	
extn_qo	Extinction along downward path (LOS)	—	
tau_xqr	Vertical Rayleigh optical depth along upward path	—	
tau_xqa	Vertical aerosol optical depth along upward path	—	
tau_qor	Vertical Rayleigh optical depth along downward path (LOS)	—	
tau_qoa	Vertical aerosol optical depth along downward path (LOS)	—	
ssr	Rayleigh scattering	—	radiation scattered into the LOS by molecules f(Rayleigh pfn).

Table A-3. Diagnostic output parameters and their meaning (continued).

Parameter Name	Parameter Meaning	Units	Notes
ssa	Aerosol scattering	—	Radiation scattered into the LOS by aerosols f(aerosol pfn)
cscat	Scattering/reflection from cloud	—	
rscat	Rayleigh double scattering into LOS	—	Small angle scattering approximation
ascat	Aerosol double scattering into LOS	—	Small angle scattering approximation
pfn	Aerosol phase function	—	Function of scattering angle s_ang
Iup	City emission function	Lm sr^{-1}	Function of psi
type_run	Point (P) or extended (E)	—	Information only
Line_skip	Print every Line_skip lines	—	Extended source only
cld_in	Clouds (Y) or no clouds (N)	—	Information only

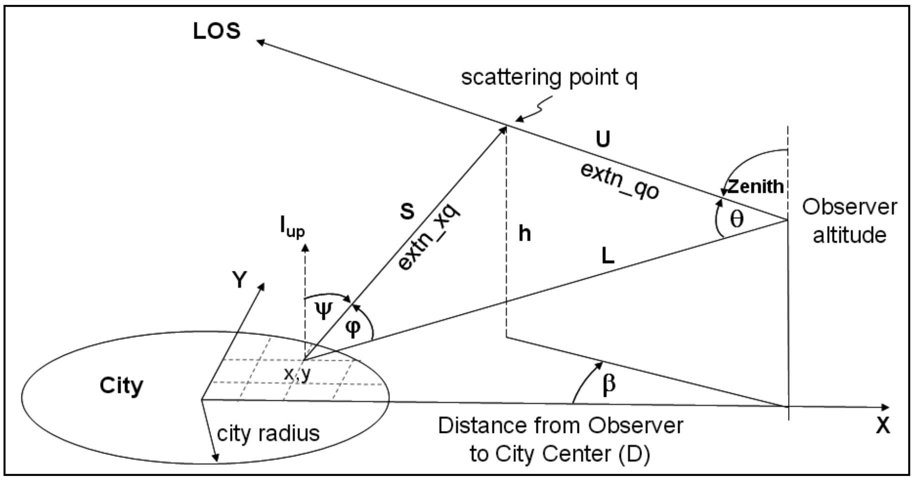

Figure A-1. Graphical representation of certain diagnostic output parameters.

A-3 Plot output

The diagnostic file output.csv is potentially very large when calculating brightness for the city as an extended source. For this reason a separate plotting output file (sb_out.csv) captures all the wavelength (in nm), the X,Y coordinates (in km) and surface brightness values (in nL) at each grid point.

Appendix B. AIM Output Using Sample Data

diagnostic/plot files opened

Name Country/City:	USA/Denver
Date: month/day/year:	3/ 2/2011
UTC	0030
City Latitude:	39.76
City Longitude:	-104.99
City Population:	1300000.
City radius:	15.0 km
City illumination:	1000. lumens/head
City altitude:	2. km
Observer height:	0.00 km
Observers zenith distance	0.00 degrees
Azimuth:	0.00 degrees
Distance from observer to city:	13.60
Garstang clarity factor K:	0.50
Surface albedo:	0.15
% of light above horizontal:	0.15

Beginning/Ending wavelength interval 0.400/0.700 um

Background Night-Sky Brightness = 17.6 nL

City Brightness w/o clouds

zenith degrees	azimuth degrees	D (km)	back (nL)	front (nL)	total (nL)	Source type
0.000	0.000	13.600	44.910	732.995	777.905	E

Lunar elevation angle = -25.73 degrees (below horizon)
Lunar azimuth angle = 271.36 degrees
Lunar phase angle   = 147.96 degrees

Lunar brightness   = 2.0303E-12 lumens/m^2

Total broadband brightness w/o clouds =   795.5 nL or   0.00796 lm/m^2

%	Light Type(s)
10.00	Mercury Vapor
5.00	LPS

This appendix is presented in its original form without editorial changes.

55.00	HPS
20.00	Metal Halide
10.00	Incandescent

Spectral Radiances

wavelength um	nL	radiance w/m^2/sr/um
0.401	78.684	1.1520E-06
0.425	66.551	9.7439E-07
0.451	72.970	1.0684E-06
0.475	122.602	1.7951E-06
0.500	230.089	3.3688E-06
0.526	51.092	7.4806E-07
0.550	174.338	2.5525E-06
0.575	380.595	5.5724E-06
0.601	799.678	1.1708E-05
0.625	265.943	3.8937E-06
0.651	149.042	2.1822E-06
0.675	208.191	3.0482E-06

Clouds Selected

Upper layer: fractional cover: 0.10, type: Ci-Cs
- thin cloud

Middle layer: fractional cover: 0.10, type: As-Ac
Lower layer: fractional cover: 0.90, type: Sc-St

Lunar brightness under clouds = 2.0303E-12 lumens/m^2

City Brightness (cloud reflection only)

zenith degrees	azimuth degrees	D km	back nL	front nL	total nL	Source type	cloud base ht km
0.000	0.000	13.600	50.393	1519.281	1569.674	E	1.10

Total broadband brightness = 2365.2 nL or 0.02365 lm/m^2

%	Light Type(s)

10.00	Mercury Vapor
5.00	LPS
55.00	HPS
20.00	Metal Halide
10.00	Incandescent

Spectral Radiances

wavelength	radiance	
um	nL	w/m^2/sr/um
0.401	221.710	3.2461E-06
0.425	186.823	2.7353E-06
0.451	206.686	3.0262E-06
0.475	354.389	5.1887E-06
0.500	674.069	9.8692E-06
0.526	141.964	2.0785E-06
0.550	507.087	7.4244E-06
0.575	1121.633	1.6422E-05
0.601	2368.673	3.4680E-05
0.625	781.884	1.1448E-05
0.651	435.755	6.3800E-06
0.675	612.783	8.9719E-06

1755 records read from unit 25
sorting...

15809 records read from unit 25
sorting...

end sort on unit 25

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Appendix C. Population of Select Worldwide Cities (cities_info.dat) Their Latitude and Longitude in Decimal Degrees (Metropolitan Areas Used When Available)

Population	Country	City	Latitude	Longitude
349000	Afghanistan	Herat	34.333	62.200
2536300	Afghanistan	Kabul	34.517	69.200
324800	Afghanistan	Quandahar	30.996	65.476
300600	Afghanistan	Mazar-e Sharif	67.110	67.110
56200	Afghanistan	Baghlan	36.120	68.703
300000	Albania	Tirane	41.332	19.817
4447000	Algeria	Algier	36.775	3.060
22390	Andorra	Andorra la Vella	42.500	1.500
2000000	Angola	Luanda	13.232	13.232
21514	Antigua and Barbuda	St. John's	17.118	-61.846
12431000	Argentina	Buenos Aires	-34.667	-58.500
1315500	Argentina	Córdoba	18.917	-96.917
1226000	Armenia	Yerevan	40.167	44.517
29998	Aruba	Oranjestad	12.517	-70.033
1040719	Australia	Adelaide	-34.917	138.583
21622	Australia	Alice Springs	-23.700	133.883
1676389	Australia	Brisbane	-27.467	153.033
307700	Australia	Canberra	-35.283	149.133
66291	Australia	Darwin	-12.467	130.833
3188000	Australia	Melbourne	144.963	144.963
1256035	Australia	Perth	-31.933	115.833
3665000	Australia	Sydney	-33.867	151.207
128808	Australia	Townsville	-19.217	146.800
1600000	Austria	Vienna	48.200	16.367
1713300	Azerbaijan	Baku	40.367	49.883
171542	Bahamas	Nassau	25.066	-77.339
155000	Bahrain	Al-Manamah	26.217	50.567
140401	Bahrain	Manama	26.215	50.588
10979000	Bangladesh	Dhaka	23.717	90.417
6700	Barbados	Bridgetown	13.100	-59.617
1666000	Belarus	Minsk	53.850	27.500
949070	Belgium	Brussels	50.833	4.333
5845	Belize	Belmopan	17.217	-88.800
30340	Bhutan	Thimphu	27.533	89.717
713400	Bolivia	La Paz	-16.500	-68.167
310000	Bosnia	Sarajevo	43.850	18.383
138000	Botswana	Gaborone	-24.750	25.917
1800000	Brazil	Brasília	-15.783	-47.917
3699000	Brazil	Porto Alegre	-30.028	-51.229
3307000	Brazil	Recife	-8.100	-34.883

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10556000	Brazil	Rio de Janeiro	-22.900	-43.233
3180000	Brazil	Salvador	-12.963	-38.512
17711000	Brazil	Sao Paulo	-23.533	-46.617
52300	Brunei	Bandar Seri Begawa	4.883	114.933
1113674	Bulgaria	Sofia	42.667	23.300
500000	Burkina	Ouagadougou	12.367	-1.517
300000	Burundi	Bujumbura	-3.367	29.317
900000	Cambodia	Phnom Penh	11.550	104.917
1299446	Cameroun	Yaound	3.850	11.583
3401000	Canada	Montreal	45.545	-73.639
1130761	Canada	Ottawa	45.417	-75.717
24570	Canada	Riviere-du-Loup	47.833	-69.269
715515	Canada	Quebec	46.833	-71.250
233923	Canada	Saskatoon	52.167	-101.533
4657000	Canada	Toronto	43.650	-79.383
2116581	Canada	Vancouver	49.267	-123.117
5113149	Canada	Toronto	43.670	-79.387
694668	Canada	Winnipeg	49.883	-97.150
61797	Cape Verde	Praia	14.917	-23.517
529555	Chad	N'Djamena	12.167	14.983
5261000	Chile	Santiago	-33.450	-70.667
12033000	China	Beijing	39.917	116.433
5566000	China	Changchun	43.887	125.325
5293000	China	Chengdu	30.711	104.088
3896000	China	Chongging	29.555	106.548
3153000	China	Dalian	38.914	121.616
5162000	China	Guangzhou	23.127	113.342
3763000	China	Handan	36.610	114.481
6389000	China	Hangzhou	30.274	120.173
5475000	China	Harbin	45.750	126.683
6097000	China	Hong Kong	22.320	114.239
4789000	China	Jinan	36.665	116.995
3375000	China	Nanjing	32.056	118.798
4376000	China	Qingdao	36.108	120.416
14173000	China	Shanghai	31.100	121.367
5681000	China	Shenyang	41.828	123.416
10239000	China	Tianjin	39.104	117.252
4750000	China	Wuhan	30.583	108.900
3352000	China	Xi'an	34.265	108.944
6834000	Colombia	Bogota	4.600	-74.083
3831000	Colombia	Medellin	6.251	-75.576
937580	Congo	Brazzaville	4.233	15.233
5068000	Congo	Kinshasa	-4.300	15.300
315909	Costa Rica	San Jose	9.933	-84.083
3359000	Cote d'Ivoire	Abidjan	5.317	-0.083
930753	Croatia	Zagreb	45.800	15.967
2241000	Cuba	Havana	23.133	-82.367
186400	Cyprus	Nicosia	35.167	33.367
1215771	Czech Republic	Prague	50.100	14.433
1339395	Denmark	Copenhagen	55.750	12.417

395000	Djibouti	Djibouti	11.550	43.167
15853	Dominica	Roseau	15.300	-61.383
3601000	Dominican Republic	Santo Domingo	18.467	-69.900
1500000	Ecuador	Quito	-0.233	-78.500
3995000	Egypt	Alexandria	31.214	29.944
150000	Egypt	Aswan	24.083	32.933
10772000	Egypt	Cairo	30.050	31.250
972810	El Salvador	San Salvador	13.667	-89.167
400000	Eritrea	Asmara	15.333	38.967
471608	Estonia	Tallinn	59.433	24.717
2200186	Ethiopia	Addis Ababa	9.050	38.700
2115	Falkland Islands	Stanley	-51.750	-57.933
200000	Fiji	Suva	-18.133	178.417
515765	Finland	Helsinki	60.133	25.000
630000	France	Bordeaux	44.833	-0.567
347900	France	Nice	43.700	7.250
9638000	France	Paris	48.867	2.333
419596	Gabon	Libreville	0.500	9.417
44188	Gambia	Banjul	13.467	-16.650
1279000	Georgia	T'bilisi	41.717	44.817
3471418	Germany	Berlin	52.533	13.417
3251000	Germany	Dusseldorf	51.225	6.776
6559000	Germany	Essen	51.458	7.015
3700000	Germany	Frankfurt	50.112	8.681
82220000	Germany	Hamburg	53.550	9.983
3067000	Germany	Koln	50.941	6.960
3200000	Greece	Athens	37.967	23.717
3103000	Greece	Athina	37.979	23.717
4439	Grenada	St. George's	12.067	61.733
160000	Guam	Hagatna	13.467	144.750
1150452	Guatemala	Guatemala City	14.633	-90.517
1508000	Guinea	Conakry	9.483	-13.717
200000	Guinea-Bissau	Bissau	11.867	-15.650
248500	Guyana	Georgetown	6.800	-58.167
1500000	Haiti	Port Au Prince	18.533	-72.333
310000	Herzegovina	Sarajevo	43.850	18.383
1500000	Honduras	Tegucigalpa	14.083	-87.233
4160000	Brazil	Belo Horizonte	-19.816	-43.954
2008546	Hungary	Budapest	47.500	19.083
103036	Iceland	Reykjavik	-64.150	21.850
4154000	India	Almadabad	72.566	72.566
5544000	India	Bangalore	12.967	77.583
12900000	India	Calcutta	22.500	88.333
6639000	India	Chennai	13.060	80.250
11680000	India	Delhi	28.667	77.233
6833000	India	Hyderabad	17.385	78.487
18042000	India	Mumbai	18.933	74.583
294149	India	New Delhi	28.635	77.225
3485000	India	Pune	18.520	73.857
3420000	Indonesia	Bangdung	-6.912	107.607

11500000	Indonesia	Jakarta	-6.133	106.750
2410800	Iran	Mashad	36.267	59.567
1204882	Iran	Shiraz	29.633	52.567
1378935	Iran	Tabriz	38.083	46.300
7705036	Iran	Tehran	35.667	51.433
313552	Iraq	Ad-Diwaniyah	31.978	44.900
333142	Iraq	Al-'Amarah	31.830	47.148
1100790	Iraq	Al-Basrah	30.293	47.292
428933	Iraq	Al-Hillah	32.497	44.446
292274	Iraq	Al-Kut	32.529	45.828
1174022	Iraq	Al-Mawsil	36.340	43.144
502842	Iraq	An-Najaf	31.352	44.096
424311	Iraq	An-Nasiriyah	31.039	46.236
910381	Iraq	Arbil	36.557	44.385
307229	Iraq	Ar-Ramadi	33.432	43.312
119665	Iraq	As-Samawah	43.281	43.281
683261	Iraq	As-Sulaymaniyah	45.450	45.450
6956562	Iraq	Baghdad	33.333	44.433
183486	Iraq	Ba'qubah	33.747	44.662
1100790	Iraq	Basra	30.520	47.824
910381	Iraq	Irbil	36.180	44.016
454090	Iraq	Karbala'	32.406	43.867
618149	Iraq	Kirkuk	35.468	44.395
1174022	Iraq	Mosul	36.335	43.137
2550500	Israel	Jerusalem	31.783	35.217
380000	Israel	Tel Aviv	32.066	34.778
364779	Italy	Florence	43.767	11.250
4251000	Italy	Milano	45.464	43.137
993400	Italy	Naples	40.850	14.283
3012000	Italy	Napoli	40.840	14.253
2693383	Italy	Rome	41.800	12.600
104000	Jamaica	Kingston	17.967	-76.800
1157846	Japan	Hiroshima	34.383	132.450
3377000	Japan	Nagoya	35.156	136.916
10609000	Japan	Osaka	34.678	135.507
28025000	Japan	Tokyo	35.667	139.750
963490	Jordan	Amman	31.950	35.933
280200	Kazakhstan	Astana	51.167	71.500
193300	Kazakhstan	Petropavl	54.883	69.217
2000000	Kenya	Nairobi	-1.283	36.817
151060	Kuwait	Kuwait City	29.333	48.000
631000	Kyrgyzstan	Bishkek	42.883	74.767
442000	Laos	Vientiane	17.967	102.600
874000	Latvia	Riga	56.667	106.167
1100000	Lebanon	Beirut	33.867	35.500
170000	Lesotho	Maseru	-29.317	27.483
1000000	Liberia	Monrovia	6.300	-10.783
950000	Libya	Benghazi	32.117	20.067
1682000	Libya	Tripoli	32.900	13.183
5067	Liechtenstein	Vaduz	47.133	9.533

590100	Lithuania	Vilnius	54.683	25.317
75622	Luxembourg	Luxembourg	49.617	6.133
444229	Macedonia	Skopje	42.000	21.467
1000000	Madagascar	Antananarivo	-18.867	47.500
260000	Malawi	Lilongwe	-13.967	33.817
1145000	Malaysia	Kuala Lumpur	3.133	101.700
62973	Maldives	Male	4.174	135.507
746000	Mali	Bamako	12.650	-8.000
9183	Malta	Valletta	35.900	14.533
20000	Marshall Islands	Majuro	7.083	171.133
480000	Mauritania	Nouakchott	18.150	-15.967
134516	Mauritius	Port Louis	-20.167	57.500
3908000	Mexico	Guadalajara	20.667	-103.333
18131000	Mexico	Mexico City	19.400	-99.150
3416000	Mexico	Monterrey	25.685	-100.305
676700	Moldova	Chisinau	47.000	28.833
30400	Monaco	Monaco	43.750	7.383
619000	Mongolia	Ulan Bator	47.900	106.867
3535000	Morocco	Casablanca	33.589	-7.609
1220000	Morocco	Rabat	34.033	-6.850
3017000	Mozambique	Maputo	-25.967	32.583
4458000	Myanmar (Burma)	Yangon	16.783	96.167
161000	Namibia	Windhoek	-22.567	17.100
535000	Nepal	Kathmandu	27.700	85.317
724096	Netherlands	Amsterdam	52.350	4.900
1208091	New Zealand	Auckland	-36.917	174.783
397974	New Zealand	Wellington	-41.283	174.783
974000	Nicaragua	Managua	12.100	-86.300
398265	Niger	Niamey	13.533	2.083
339000	Nigeria	Abuja	9.167	7.183
13488000	Nigeria	Lagos	6.450	3.400
2741260	North Korea	Pyongyang	39.000	125.783
483401	Norway	Oslo	59.917	10.750
350000	Oman	Muscat	23.617	58.633
201000	Pakistan	Islamabad	33.667	73.133
11774000	Pakistan	Karachi	24.850	67.033
6030000	Pakistan	Lahore	31.545	74.341
12299	Palau	Koror	7.350	134.517
450668	Panama	Panama City	8.967	-79.533
250000	Papua New Guinea	Port Moresby	-9.500	147.117
502426	Paraguay	Asuncion	-25.267	-57.667
7443000	Peru	Lima	-12.050	-77.050
10818000	Philippines	Manila	14.583	120.983
458053	Poland	Gdansk	54.383	18.667
3488000	Poland	Katowice	19.024	19.024
1642700	Poland	Warsaw	52.250	21.000
677790	Portugal	Lisbon	38.733	-9.133
422000	Puerto Rico	San Juan	18.467	-66.117
300000	Qatar	Doha	25.250	51.600
2351000	Romania	Bucharest	44.433	26.100

9299000	Russia	Moscow	55.750	37.700
5132000	Russia	Saint Petersburg	59.933	30.333
594701	Russia	Vladivostok	43.150	131.883
232733	Rwanda	Kigali	-1.933	30.067
32859	Samoa	Apia	-13.831	-171.752
2397	San Marino	San Marino	43.933	12.433
3328000	Saudi Arabia	Riyadh	24.650	46.767
1199629	Scotland	Glasgow	55.883	-4.250
1729823	Senegal	Dakar	14.667	-17.433
1574050	Serbia	Belgrade	44.833	20.500
25000	Seychelles	Victoria	-4.633	55.467
1300000	Sierra Leone	Freetown	8.500	-13.250
3587000	Singapore	Singapore	1.300	103.833
446600	Slovakia	Bratislava	48.167	17.167
330000	Slovenia	Ljubljana	46.067	14.500
35288	Solomon Islands	Honiara	-9.467	159.950
900000	Somalia	Mogadishu	2.033	45.350
3092000	South Africa	Cape Town	-35.917	18.367
1480530	South Africa	Johannesburg	-26.133	27.900
749921	South Africa	Port Elizabeth	-33.967	25.600
1104479	South Africa	Pretoria	-25.750	28.200
4239000	South Korea	Puan	-13.828	-171.744
11968000	South Korea	Seoul	37.533	127.000
1510000	Spain	Barcelona	41.383	2.183
4072000	Spain	Madrid	40.400	-3.683
1994000	Sri Lanka	Colombo	6.917	79.867
924505	Sudan	Khartoum	15.600	32.533
200970	Suriname	Paramaribo	5.833	-55.167
47020	Swaziland	Mbabane	-26.333	31.133
703627	Sweden	Stockholm	59.333	18.050
129423	Switzerland	Bern	46.950	7.433
1080000	Switzerland	Zurich	47.367	8.550
1549932	Syria	Damascus	33.500	36.300
2643439	Taiwan (ROC)	Taipei	25.083	121.533
524000	Tajikistan	Dushanbe	38.633	68.850
1360850	Tanzania	Dar es Salaam	-6.850	39.300
7221000	Thailand	Bangkok	13.733	100.500
366476	Togo	Lome	6.133	1.217
34000	Tonga	Nukualofa	-21.150	-175.233
52451	Trinidad and Tobago	Port-of-Spain	10.633	-61.517
887800	Tunisia	Tunis	36.800	10.183
3190000	Turkey	Ankara	39.917	32.833
9413000	Turkey	Istanbul	41.017	28.967
518000	Turkmenistan	Ashgabat	41.332	19.817
3839	Tuvalu	Funafut	-8.517	179.217
773463	Uganda	Kampala	0.317	35.417
7640000	UK	London	51.500	-0.167
2637000	Ukraine	Kiev	50.417	133.717
363432	UAE	Abu Dhabi	24.467	54.367
6000000	USA	Boston	42.359	-71.058

77000	USA	Boulder	40.060	-105.200
6945000	USA	Chicago	41.883	-87.650
3912000	USA	Dallas	32.781	-96.797
1300000	USA	Denver	39.755	-104.988
3785000	USA	Detroit	42.330	-83.046
876156	USA	Honolulu	21.300	-157.817
5,946,800	USA	Houston	29.750	-95.367
13129000	USA	Los Angeles	34.050	-118.250
16626000	USA	New York	40.717	-74.000
4398000	USA	Philadelphia	39.952	-75.164
4051000	USA	San Francisco	37.775	-122.419
3927000	USA	Washington D.C.	38.530	-77.024
1330440	Uruguay	Montevideo	-34.883	-56.183
2106000	Uzbekistan	Tashkent	41.267	69.217
26100	Vanuatu	Port Vila	-17.750	168.300
3153000	Venezuela	Caracas	10.500	-66.933
345489	Venezuela	Merid	8.400	-71.133
3678000	Vietnam	Hanoi	21.017	105.867
6424519	Vietnam	Ho Chi Minh City	10.767	106.717
1972011	Yemen	Sanaa	15.400	44.233
1168454	Yugoslavia	Belgrade	41.332	19.817
1184169	Zimbabwe	Harare	-17.833	31.500

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List of Symbols, Abbreviations, and Acronyms

AGL	Above Ground Level
AIM	Army Illumination Model
Ac	Altocumulus
As	Altostratus
ASCII	American Standard Code for Information Interchange
Cb	Cumulonimbus
Ci	Cirrus
Cs	Cirrostratus
CSV	Comma Separated Value
Cu	Cumulus
GMT	Greenwich Mean Time
LED	Light Emitting Diode
LOS	Line-of-Sight
MSL	Mean Sea Level
St	Stratus
Sc	Stratocumulus
UTC	Coordinated Universal Time

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